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ABSTRACT

This study explores the nature and meaning of various epistemological and affective issues that shape elementary teachers' work, such as ways of knowing, beliefs about the nature of science, values, emotions, and teachers' images of themselves as knowers. Through analyses of two teachers' narratives, classroom observations, and instructional materials, this research reveals how teachers' emotions and values are significant dimensions of science teaching and can explicitly or implicitly be part of their personal and professional development. This study offers an alternative perspective to discussions on the relationship between teachers' beliefs and classroom practice, and it presents a more valid methodological approach to avoid past research assumptions that teachers' beliefs are necessarily reflected in classroom practice. Contains 53 references. (DDR)

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Epistemological and Affective Dimensions of Elementary Science Teachers' Work

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Abstract

This study explores the nature and meaning of various epistemological and affective issues that shape elementary science teachers' work such as ways of knowing, beliefs about the nature of science, values, emotions, and teachers' images of themselves as knowers. Through analyses of two teachers' narratives, classroom observations, and instructional materials, this research reveals how teachers' emotions and values are significant dimensions of teaching science and can explicitly or implicitly be part of their personal and professional development. This study offers an alternative perspective to current discussions about the relationship between teachers' beliefs and classroom practice; also, it points out a more valid methodological approach to avoid past research assumptions that teachers' beliefs are necessarily reflected in classroom practice.

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Epistemological and Affective Dimensions of Elementary Science Teachers' Work

This study offers an alternative perspective to current discussions about the relationship between teachers' beliefs and classroom practice. I explore the nature and meaning of various epistemological and affective issues that shape elementary science teachers' work such as ways of knowing, beliefs about the nature of science, values, and teachers' images of themselves as knowers. I take up these issues to examine and describe *how* knowledge, emotions, caring and values are implicated in teachers' teaching. I argue that we need to reassess the role of emotions in relation with epistemology and what there is to be gained from privileging a *holistic* attention to teachers' work, one that does not ignore affectivity any more. Exploring teachers' epistemological and affective perspectives can provide a useful framework for at least two reasons. First, through analyses of teachers' narratives, classroom observations, and instructional materials, this research reveals how teachers' emotions and values are significant dimensions of teaching science and can explicitly or implicitly be part of their personal and professional development. Second, it points out a more valid methodological approach to avoid past research assumptions that teachers' beliefs are necessarily reflected in classroom practice.

The argument for recognition of the epistemological and affective dimensions in teaching draws from several fields of research: epistemology, teacher knowledge, research on teachers' conceptions on the nature of science, caring, and affect. I have turned to research fields not usually employed in the study of teachers such as philosophy (epistemology), and I bring these together to construct the context for the discussion that follows.

Researchers have argued about the importance of knowledge and values in teaching (Fenstermacher, 1986; Lyons, 1990; Noddings, 1986). Especially, in science education most research on teachers' conceptions about the nature of science focuses on examining whether or not teachers' conceptions are "adequate" according to fairly arbitrary subject matter standards (Lederman, 1986, 1992). More recently, researchers have proposed comparisons and categorizations derived from the history and philosophy of science (Brickhouse, 1989; Duschl & Wright, 1989; Koulaidis & Ogborn, 1989; Loving, 1991). Researchers have increasingly emphasized the need to describe teachers' knowledge (Ball, 1991; Borko, Bellamy, & Sanders, 1992; Carlsen, 1991b; Hollon, Roth & Anderson, 1991; Shulman, 1986, 1987; Smith & Neale, 1989) and teachers' beliefs (Brickhouse, 1991; Clark & Peterson, 1986; Kagan, 1990). Sometimes, the results of the research are contradictory; a case study of three teachers has suggested that teachers' conceptions about the nature of science have little or no effect on classroom practices (Duschl & Wright, 1989), whereas other studies found that teachers' beliefs

affect their classroom practices (Brickhouse, 1989, 1990; Briscoe, 1991; Zeidler & Lederman, 1989).

My study builds upon Lyons (1990) ideas on the relationship between students and teachers as knowers which she calls *nested knowing* "that is, students and teachers are considered to have nested, interacting epistemological perspectives" (p. 162). The study of elementary science teachers' epistemologies appears to be a significant way of understanding how knowledge is constructed, defined, and negotiated in schools. This type of research serves also as a powerful tool for revealing aspects of the complex nature of teachers' work and interpreting their practical choices (Lyons, 1990). In *Women's Ways of Knowing*, Mary Belenky and her colleagues suggest the significance of alternative ways of knowing and develop an epistemology that acknowledges *how individuals* come to know through relationships with others. This work reminds us of three things, Lyons (1990) argues: that individuals can hold various epistemological perspectives, that such perspectives may change over time, and that within a given epistemological perspective, approaches to knowing may vary (p. 170). Furthermore, Osborne (1998) argues that teachers' epistemologies are created and maintained emotionally as well as intellectually. Praxis, Osborne writes, proceeds from teachers' personal epistemological standpoints which are only partially applicable to particular situations in the classroom. Teachers find their knowledge only partially applicable and so through teaching, the teacher becomes a learner.

In my attempt to explore the epistemological and affective dimensions in elementary science teachers' work, I find Elbaz's (1983) ideas useful and informing. Elbaz (1983) describes how teachers' practical knowledge is shaped in classroom life, and argues that teachers' feelings, values, and beliefs create *images* of how teaching should look. Also, Connelly and Clandinin (1985) expand Elbaz's framework arguing about teachers' personal practical knowledge in support of the importance of the social context of the classroom in which teachers' knowledge and emotions are socially constructed (see Jaggar, 1989; Vygotsky, 1978) through interactions and dialogue with their students.

Much of this research has focused on *what* aspects of the nature of science teachers know and on *whether or not* these aspects are reflected in classroom practice. Most of the studies do not examine the importance of the social and organizational context in which teachers teach (Carlsen, 1991a), and the significance of teachers' perspectives on knowing (Belenky et al. 1986; Lyons, 1990); also, very little attention has been paid to *how* teachers' affective development is integrated into their knowledge and beliefs.

Methods and Data Analysis

The epistemological and affective dimensions in teachers' work first emerged from a pilot study of two elementary school teachers who are very enthusiastic about teaching science. The case studies of two teachers (Marcy and Barbara) are presented here in some detail. This research

still continues for almost eighteen months with one of the teachers (Marcy), and it reveals more and more aspects of the epistemological and affective dimensions in these teachers' work. Since January of 1997, I have been working with Marcy in her classroom one or two days per week. I have been watching her teach, and I have been taking fieldnotes.

This study is a qualitative ethnographic one. The "data" consists of many pages of fieldnotes from observations, interview transcripts of taped interviews (approximately 20 hours with Marcy and 7 hours with Barbara), journal notes to myself, documents pertaining to the teachers' teaching strategies and activities, philosophy statements, school records and samples of students' work. The participants were two second-grade teachers.

These multiple data sources allowed me to construct a detailed description of the teachers' epistemological beliefs and values from a variety of perspectives. In the analysis, triangulation of the various data sources (Lincoln & Guba, 1985), and the use of constant comparative method (Glaser & Strauss, 1967; Strauss, 1987) were employed from the beginning of the data collection to establish and test working hypotheses, and to construct and develop themes that ran through the data for each of the informants. I analyzed the teachers' instructional materials (philosophical statements and lesson plans) and conducting a few classroom observations prior to interviewing them; in this way, I avoided becoming aware of their beliefs, before I observed them.

The School Context

The school where Barbara and Marcy teach is located in the southwest part of a university town about 120 miles southwest of Chicago. It is a fairly new--founded in 1988--not very large, brick building with typical school architecture. In front of the building there is a large lawn, the size of a football field. There are a few fences around the playground at the east and the west sides of the building. One of medium sized grade schools in the state of Illinois, it housed 400 students in grades K-5. There were approximately 30 staff members, including secretaries, aides, janitors, cooks, and 18 certified faculty members--one principal and seventeen classroom teachers. Students of color comprised 35% of the school population. Blacks were the most populous at 30%, followed by Latinos at 3% and Asians at 2%. Almost 55% of the students were low-income students.[1] Many of the minority children were bussed from a different part of town, however the local neighborhood of the school would be characterized as mixed in socioeconomic status between working class and professional/university classes.

When I entered the school building for the first time, I was struck by the many colors covering the walls, the hallways, the windows. The walls in the hallways outside Marcy's and Barbara's classrooms were adorned with students' paintings and drawings depicting dinosaurs and

[1] The definition for low-income students according to the district includes children who come from families receiving public aid, live in institutions for neglected or delinquent children, are supported in foster homes with public funds, or are eligible to receive free lunches.

scenes from the National Gallery of London, graphs with themes from Valentine's day, and essays about Martin Luther King and peacemaking. These displays were neither a simple decorations of the walls, nor just a colorful show. They were children's images of discoveries, products of their own journey using their gifts in understanding, and "celebrations of the wonders of the world", as both Marcy and Barbara would say. These discoveries--and I was lucky enough to participate in some of them during my visits in their classrooms--were embedded in children's hearts and souls.

Marcy and Barbara: Their Profiles and Their Classrooms

Barbara

For the two months I was in Barbara's classroom our differences in race, sex, philosophy and teaching experiences proved invaluable in our conversations. Barbara is African-American, and she has twenty years of teaching experience teaching grade school and giving workshops to teachers; I am white, I had some experiences in working with teachers, and I had only one year of teaching experience in the Cypriot educational system. I was grateful because although we were very different in many ways, these differences complemented our views in science. They enforced my belief that we see things and interpret them through the lenses we construct for ourselves, based on our experiences, beliefs, and knowledge.

Barbara had worked at this school for the last nine years; this year, she was teaching a second grade class. When she began teaching over twenty years ago she felt that: "Initially I felt I was going to go into the area of biology, but my work there was not really as rewarding or satisfying as I thought," laughed Barbara when thinking about what made her get involved in teaching. She had the opportunity to work with some children during a project while she was at the College of Agriculture and she realized that was what she wanted to do. After her graduation, she worked for a few years at the Child Development Lab, a pre-school program. This provided her with some in-depth experiences with children. "This inspired my great appreciation of the abilities of very young children and how they are able to learn in very neat ways," Barbara remarked in one of the conversations we had. In working with her, I realized that she believed that children had fascinating ideas, and if they are actively engaged in science, learning is fun and meaningful to them. I suspect that an exceptionally important part of this belief in the "magic" of science came from the fact that she always loved science herself. "Science was really big with me, and I enjoyed it tremendously. I love reading about science, so within myself there is kind of a burst or desire for new information and knowledge," Barbara told me more than once. When she was teaching, her fascination about science was obvious from her facial expressions and body language. At various time she would warmly smile at the children, change the tone of her voice modulating it with enthusiasm and excitement. I see now in a new way, how a teacher's excitement plays a significant part in teaching science. On more than a few occasions, this excitement was reflected in the children in ways that always fascinated me. "Ooh," "Aah,"

"Wow!" "This is awesome!" "Oh, my gosh! Look at that!" were frequently heard. In the course of my visits to Barbara's classroom, the children demonstrated their capacity for getting excited in many ways! Such reactions were always a celebration, a joyful expression discovering the wonders of this world.

Barbara explained to me that the reason so many students dread science was grounded on that they were not allowed the opportunity to actually grapple with scientific phenomena. Learning science would come only by "doing" science, she argued. "It's so difficult to mentally conceptualize some concepts in science. Unless you experiment with how things function, how things work, it's really hard to understand science," Barbara said in another conversation we had. During my several visits in her classroom, I witnessed many occasions in which both Barbara and her students did experiments, challenged one another's thinking, and expressed obvious excitement for what they did. Here is an excerpt of my fieldnotes during the visit in which they made experiments on the idea of water's cohesiveness.

> The experiment was about finding out how many objects would be needed to overflow some containers filled to the top with water. The students were divided in various groups. Each group had its container and was given a number of objects such as pins or paper clips. Every group was given the same kind of object but different groups were given different objects. First, the students predicted how many of the various objects it would take to overflow the containers, and they recorded their predictions. Then they tested each set by adding one object at a time carefully. After a while several students began asking for more objects saying "we need more!". They seemed surprised that they needed more than they expected. Barbara asked how many more they needed. Students made then new predictions and she gave them the number of objects they asked for. Students observed the level of water in their glasses and although they had already added many more than their initial predictions, the water did not overflow. Students were smiling, and their faces were full of surprise over the unexpected outcome of their experiments. The noise level was high. There was a lot of movement. Some students from other groups gathered around one particular table in which the number of paper clips exceeded 100 and they kept adding without the water overflowing. Everyone waited to see what would happen if they added the next paper clip. One student looked another one and said: 'Isn't that cool!'

For Barbara, "Science is the world, science is everything." It serves as an agent through which it is possible to teach everything and to challenge children's thinking. In the different times I talked to her or observed her teaching, science took many forms, such as experimentation, observation, and measurement; her goal for students was to "discover" knowledge. Although she touched upon several issues regarding the relationship between her philosophical ideas about science and her practice, the major underlying outcome of her "struggle" was always viewed through the eyes of teaching. As she explained, this "struggle" referred to her effort to connect her theoretical ideas about the growth of scientific knowledge and her practical ideas about *how* to teach science. Her views about science were grounded in two premises. First, her holistic view about science, and second, her concerns about giving the children the "right" information. These premises were the transformative agents through which she examined her philosophical ideas about science. Such ideas seldom passed through those premises unexamined. Although she held that

"science is constantly changing," she established a particularly strong idea that there are "right" and "wrong" scientific conceptions. The apparent contradiction between these two statements was never perceived as a contradiction by her. She was clear about the need to make sure that she was informed about the status of scientific knowledge. By being knowledgeable about the changing status of what is considered "right" and "wrong" by the scientists, she was able to resolve the contradiction. Her premise maintained that at a given time it was clear that some things were "wrong" and some were "right"; this accommodated sufficiently the premise for change, because in a sense nothing was stable except the changing nature of itself.

Barbara maintained, though, that "some facts remain true, and some knowledge about some areas of science probably remain constant." This was significant for example, when she taught the concept of cohesiveness, she insisted on providing the students with the *accurate* scientific definition of "cohesive" and "adhesive." Her belief was that these definitions were accurate and that they would not change. She enacted this belief by teaching that these particular facts about cohesiveness would remain constant. Her teaching experiences in showing that these definitions remained repeatedly constant shaped her philosophical ideas that some knowledge in science would not change. It seems to me that her philosophical beliefs about the growth of scientific knowledge required evidence in her teaching practice; this resulted in a situation in which her beliefs were tightly bound to her teaching practice and not the other way around. In other words, her philosophical ideas about science were very pragmatic and very close to her teaching practice; they were not allowed to become utopian.

Her belief that some things remain constant justified her definition of discovery. For Barbara discovery meant that if some things remained constant, then we could discover them. Barbara states:

> I really believe in the idea of discovering knowledge. Many times kids ask me, 'If we put a Dr. Pepper can in the freezer, why does it explode?' 'Why don't you go discover it? That's a good area we can explore. Let's try and find out.' So, I believe in constructivist learning. Kids can create their own kind of design, their own kinds of experiments. And there is a lot of learning... unforgettable learning.

Barbara's belief that learning is about discovering new things causes her to emphasize investigation and understanding scientific processes. "Students need to understand scientific principles. There is so much basic information that we need to know." For her, there is some information that students need to go and find. But also students construct knowledge internally. She thinks that "it has to be both."

> If it wasn't then we wouldn't continue to come up with new ideas, new research information, because someone has to internalize them. There are some things already there and then there is more being constructed. So, I have to say it's both, because whenever we strive for new ideas, these ideas are based on old ones.

Another factor contributing to Barbara's philosophy about the nature of science was the importance she attributed to scientific processes such as observations. Both her beliefs and her practice were used as a reference point to ground her interpretations about the sense and the worth of observations. For example, in one of the observation sessions she explicitly emphasized to the children that "One thing about scientists is the skills they need to have. One of these skills is observation. It takes good observation skills for someone to be a scientist." Also, in one of our conversations she mentioned that observations are an important part of the scientific process along with experimentations and measurements. All these processes together provide the children (and scientists) the tools to wonder and to discover new knowledge. Again, there was awareness and consciousness that contributed a close link between her beliefs about observations and her practice. The significance of observations was concretized as it was practiced in her teaching; it was so strongly embedded in practice that it was never seriously challenged by ideas such as "our senses sometimes might deceive us." Her notion of discovery seemed in conflict with her beliefs that scientific knowledge is constructed. This proved to be an important point because underneath it lay the fact that she held at least two contradictory understandings of the nature of science; one referring to the purposes of science, and the other to the processes of practicing science. The contradiction about the purposes was based on the premise that in discovery the thing being discovered is determined very clearly, because its properties are known; however, in the construction of knowledge every potential avenue is open, and the properties of the thing being constructed are not known beforehand. In discovery there are clearly determined processes which lead to the thing that remains constant; others before us defined those processes very meticulously. However, in the construction of knowledge the processes need to be re-invented in each new context. Nevertheless, for Barbara the above contradictions remained "virtual" unconsciously held models, because they were never articulated. Therefore, they did not seem to create any "real crisis."

It seems to me that there were at least two underlying assumptions in her philosophy about learning. First, some knowledge is "out there" and we need to find it. Second, some knowledge needs to be constructed by us. The common ground for both assumptions was that discovery was the most appropriate method to either find knowledge or construct it. However, the common ground linked contradictory domains of meaning, treating them as one. The premise that some knowledge existed "out there" could potentially imply that the process of constructing it was of no importance. Barbara employed a single meaning for both "finding" and "constructing" knowledge. Linking two distinct realms of meaning into one was appropriate and sufficient for her. It provided her a sense of continuity in the course of discovering knowledge. At the same time, though, this link carried the disguised contradiction.

Her belief that "children don't form theories" marked the beginning of a particularly interesting conversation, because I believed the opposite. Barbara was very assertive about it. She believed that children have theoretical ideas, however, their ideas do not comprise theories. Her rationale was the following.

> Theories are basically based on an enormous amount of research. You theorize based on the information you gather. What the children say is based on their experiences. Their purpose is not to really explore that particular topic whereas in theories you have a particular topic where you do research. Theory goes beyond the initial beliefs you may have which maybe where the students are.

Barbara's belief was grounded on the standards she had in her mind about what made a scientific theory. These standards, such as the rich background information, were not met by children's ideas. Here, I disagreed with her because I think that children do have a rich background information, a different one compared to the adults' background but nevertheless one that is rich, imaginative, and full of alternate realities. She further explained that there were significant differences between the practice of science by scientists and the science done by children in the classroom. "Scientists have tools," she said. "They can have better experiments. Children are limited, perhaps, in what they can formulate and what they can inquire relative to science ideas and concepts. There are also many variances in experiences between scientists and children." This was the reason, according to Barbara, that "children can't understand science, so they call it 'magic.' 'Teacher, it's magic!' They call it magic rather than looking at the underlying principles of things. Children have limited vision, perhaps they have tunnel vision whereas scientists have peripheral vision." I agreed with her that children don't have as many experiences as scientists have, however, I thought that one possible reason that science is magic to them is that it creates remarkable, and unexpected astonishment to them or it is aesthetically appealing. On the other hand, she also recognized that scientists and children had similarities. She pointed out that both scientists and children had at least three similarities. First, they are both curious; "curiosity is what drives a lot about science," she said. Second, "students are very inspired by opportunities to investigate and experiment and so are scientists." Finally, both children and scientists want to find out how things work.

Barbara constructed an orderly frame in which the threshold between theories and non-theories and between scientists and children was well defined. This threshold divided her frame into two distinct areas: one for scientists' science, the other for children's science. These two areas seemed to be "incommensurable", to use Kuhn's term. In other words, although there were some similarities between them, each type of science was very distinctive in terms of its goals, its practices and its boundaries. Barbara had a unified idea about the importance of discovery in science, however, she had a fragmented notion of the practices of science. She believed in two

kinds of science, thus imposing certain measures of excellence regarding what were some standards for the practice of science.

Barbara described the characteristics of the science learner in her classroom. She related those characteristics with her rationale for promoting investigation and discovery. "Children should be engaged in learning science. They should be given opportunities for discovery in their learning. They have ideas; some of them are theoretical but some of them are kind of funny. I think it's wonderful to listen to them." Barbara encouraged "wonderment and discovery" because, as she explained, "children begin building their knowledge when they say 'I wonder what would happen if...' I think this is how they move from that 'external' knowledge [one could find it 'out there'] to find out something for themselves about science." Wonderment was a big issue for Barbara. It was a natural quality she cultivated in herself for learning new things. Wonderment was a serious commitment in the learning process. It was accompanied by her passion and her excitement. Her students were always excited when they were engaged in scientific investigations. She managed to ignite students' excitement with her own excitement. Her students' excitement was a mirror image of her own love and passion for science. The following excerpt was taken from our first conversation.

> Children are very excited about science. I guess my enthusiasm is reflected in them. It's just exciting. There are so many things you can do in science, you can make it fun as well as kids are really learning. I feel that students have a lot to offer. For example, I begin my year with an activity I call 'Great Expectations'. And what that is about is what would you like to learn about. And so students give me various responses. So, that helps me to give some direction as to what kind of things I want to cover, what kids know and what they are interested in learning about. I think they love the opportunities to do lots of things, to learn things... the real impact that has in their lives.

"Learning should be exciting," Barbara mentioned to me several times. Indeed, learning was exciting in her classroom, as it seems from the earlier description of the experiment on water's cohesiveness. In another conversation we had, she pointed out that "learning should not be frustrating to students. Neither should it be boring. Students need to be challenged in an atmosphere that is conducive to a desire for learning." Her attitude about the excitement was that needed to guide students' learning was intertwined in both her words and her practices. Barbara combined her ideas about respecting students' learning styles with her beliefs about teaching information that students needed to know, in a way that was exciting.

"Scientific knowledge and scientific principles are part of science teaching," according to Barbara. During our first conversation she pointed out to me that "any concept that we are teaching needs to have a structure. And when I say that, I feel that there is a science 'vehicle' through which we should kind of plug in scientific knowledge." These beliefs were exemplified through her practices of encouraging children to discover knowledge. She admitted the fact that changing scientific knowledge changed the ways science was taught. Therefore, she would try to provide an

environment within which students would want to find out about things. But in the meantime, whenever she found an opportunity, she provided them with specific information and terminology that she felt students should know. However, she clarified to me that she would use the correct scientific terminology even if the students would never hear about some things until they would go to high school; she wanted to expose the students to scientists' terminology. For example, during one of my observations she asked the students what it meant to say that "water is cohesive." One of the students answered that it meant: "water has hydrogen and oxygen." Barbara repeated her question and insisted on "what does water has to do with 'cohesive'?" She waited for a few seconds and without rejecting the student's answer she wrote on the board "cohesive" and "adhesive" explaining the two terms.

Barbara's arguments for this method of teaching, a blend of encouraging children to discover knowledge and providing them the correct scientific information, was straight forward. "If you know that this is the most effective way that children can learn, why not use it?" she said. For Barbara the organizational context of her classroom was in a dialectical relationship with the social context as defined by the students she had every year. An example of this is seen in the following excerpt which was taken from our last conversation.

> I know some things about science. I have some specific ideas about how to teach science, but because students have different needs, I need to have them engaged in science so the mannerisms change. For instance, some years I may teach a particular area very differently than I teach it another time. This is based on how students learn, and what particular environment a group of students may create within my class. Sometimes, I've been able to teach more in depth or take science lessons to a broader horizon because of the students. I have ideas about what I want to do, but the direction in which we'll go depends a lot on the students that I serve.

As a result of the continuous interaction between the social and the organizational context in her classroom, a continuity was established which strengthened the rationale for her teaching philosophy. On the other hand, this rationale served as the agent of constructing the thread of her philosophy, in order to understand better the classroom context.

Marcy

"The structure of my classroom and all of its ways, whether you are talking about the schedule, the physical way the room is set up, there isn't one area that has more importance than another. As well as the kinds of activities that go on," Marcy said in one of the very first meetings we had. I was immediately struck by the unique structure of Marcy's classroom, full of creativity and imagination. Time and twenty years of teaching experiences had sharpened every object, every picture that was in her classroom. Every piece had been placed there in connection with every other, all carrying their own stories collected either by her or by the children. "Frequently, children bring things from the playground. 'Oh, look! I found this!' and we look at this.

Sometimes they bring snakes. It's important for children to be as involved as possible in this area. So I ask them to find a place to put the things they bring," said Marcy about the way the several "centers" are put together in her classroom.

In Marcy's room you could imagine exotic snakes and large turtles instantly acquire their flesh and "wear" their skins on their backs, become alive and travel outside their "Reptile House", their temporary home. Or sometimes you could pretend that you were in London; a special corner stood like a small house bearing pictures, puppets, books, royal swords, maps and many more artifacts from London. In one corner on the wall, there was an aquarium made by kindergartners a few years back. It had fish, starfish, sea plants, corals, all made and brightly colored by the children using paper, cardboard, paints, and other materials. Next to the aquarium, there were rubber insects and ladybugs hanging from the ceiling with a thin string, parrots with tiny bluish and yellowish faces, and many other birds. Marcy had traveled in many places all over the world. She always collected some things from each place and brought them to her class. All those objects portray her belief in the connectedness of the world.

Marcy is White and she has been in this school for the last seven years. She began teaching more than twenty years ago. She mostly taught early grades; this year she was teaching at second grade. Marcy explained to me in our first meeting that her early experiences influenced her philosophy about science. "Other than growing up in a family of educators--my mother was a teacher and so I remember being out collecting insects with her--science wasn't that interesting. I don't think I had any conceptual understanding of it. So I recognize why science can't be interesting or isn't interesting to me and how this might come up to my students, " she said. She pointed out to me that her mother taught in a style that was very hands-on, much like her own style of teaching. "So, I would see that model and I think that seemed natural for me to do. But it wasn't until later that it really connected to me that this learning style was very important to me personally and became a component in my classroom".

Marcy identified two significant turning points in her life in terms of how much she was influenced to discover the idea of "the connectedness of the world" she referred to. The first one was a biology course she took as a sophomore in high school. Until then most of her experiences had been textbook science, memorizing facts and terms. What was special about this class was the fact that it was taught in a hands-on approach which made science real to her. The second event, one that was a major shift in her life, happened in the past ten years. Marcy explained this when she described her experiences from teaching kindergartners. Here is our conversation toward the beginning of that first meeting we had:

"I think it was not until I taught kindergarten that I realized how important science was," she said.

"Why was kindergarten such a different experience?" I asked.

"I think probably some of that had to do with the fact that I was forced with kindergartners not to rely on any kind of reading of text in what I was to do. It had to be totally exploring. We had to do lots of hands-on things together," she replied.

In another conversation we discussed the meaning of science, as she had come to construct it during her teaching career.

"Marcy," I asked, "what does 'science' mean to you?"

She said, "One of the components that I see as exciting about science is the idea of investigation. Either having questions and wanting to discover the answers or even pondering over the questions and not ever getting to the answer."

I nodded. For most of my life, I was taught that finding an answer was very important. It never occurred to me in my whole grade school life that I would ever believe, as I do now, that not getting the 'right' answer was ever acceptable. Now there's something I should really explore, I thought.

She remained silent for a few seconds, longer than usual. She often did that when she wanted to be very precise about the words she would use. "Those terms 'right' and 'wrong' have little meaning" she said, and added, "My sense is that everything is a continual refining of our understanding. Life is a series of discoveries." She spoke very quietly while smiling warmly.

Marcy emphasized at several times during our discussions that science for her was the process of constant refining of our understanding. In fact, she considered "all of us as scientists." This was based on the assumption that the process of discovery was the most important. After all, she pointed out to me, we are all involved in some kind of "discovering." One of her premises was that "information is relative" in the sense that "our ideas change, our understandings change, and even the physical things may change." This thought could explain her second premise, the vulnerability and defenselessness of a statement proclaiming the "correctness" of an answer in science. As Marcy put it, "There is no definitive, accurate concept of anything." However, she frequently mentioned to me that some would disagree with her, implying that her ideas might not be acceptable especially among "hard-core scientists", as she called physicists, biologists and so forth. Presumably, she wanted to assure me that her feelings and thoughts could potentially bring negative reactions. Nevertheless, she insisted that holding these ideas did not mean that she wanted to deprive children of the opportunity to gain "accurate information."

Naturally, my next question was, who decides what is "accurate" if the notion of accuracy is relative, as Marcy proclaimed. Underlying this was her conviction that "accurate is what we currently, in the scientific world, recognize as the 'correct' answer or the 'accurate' answer at the moment." While she did believe in the relativity of accuracy, at the same time her concerns about giving "accurate" information to the children did override her appreciation of the fragility of "accuracy." On more than one occasion, during my presence in her class, she wanted to make sure that the correct scientific terminology was used. For example, she referred once to a student's question about what vertebrates were. After she encouraged students with several probing questions to share their ideas, she told them that "'vertebrates' is the scientific term that is used for animals which have a backbone". The observation sessions brought to light other examples of the

internal "virtual" inconsistencies between Marcy's overt philosophy of what science was and her pragmatic model of teaching. The inconsistencies were not real. They were "virtual" because her belief in the relativity of what is "correct" in science, gave no basis for claiming the superiority of one "correct" idea over another. Yet, she believed in choosing one "correct" answer and acting according to that choice. In other words, her pragmatic notion of science teaching could potentially contradict her philosophical beliefs, yet no more so than anyone with ideas like hers. On the other hand, though, her position was not completely justified. These inconsistencies may remain "virtual" but in cases of "crisis," they become real contradictions between philosophical beliefs and practices that require some reconciliation. An example of a "crisis" occurred in the discussion about "right" and "wrong," as follows.

Often Marcy provided an explanation of her reasoning for crystallizing her views around the use of "right" and "wrong." Inevitably, she found these characterizations inadequate but useful as frames of reference. In another light, as a definitional exploration, she touched on the categorization of people as "right" and "wrong," saying that it was a result of social factors. "We have forgotten," she said "that there is not simply 'right' and 'wrong.' Little by little we teach the children that it is either the one or the other. I think, somehow, we often forget that we can help children develop." Marcy did not exclude herself from this. She recognized that she was communicating in her classroom that there was still "right" and "wrong," in terms of children's behavior, by enforcing regulations with rewards and punishments. At the beginning, I was puzzled because I could not identify the conflict between her ethical perceptions about "right" and "wrong," and her actions in the classroom. After all, I thought, it would be really chaotic to claim that there was no "right" or "wrong" if, for instance, one child hit another. Eventually, I recognized that this "disequilibrium" between idealistic conceptions and pragmatic situations did create a "crisis." However, despite Marcy's ambivalence, her decision to contradict her philosophical position was necessary to avoid chaos. Her philosophical perceptions about the world framed her reactions in a pragmatic situation, but this frame was not static; her reactions in a pragmatic situation framed her perceptions as well. This suggests that these two influences were in a constant dynamic interaction.

Here is an example to illustrate this interaction and the reconciliation she achieved between her philosophical conceptions and a pragmatic situation. Marcy emphasized the profound significance of observations in our lives and in science. "What we observe," she said "is based on what we already know." However, there are times, as she pointed out, that even our senses deceive us. Nevertheless, observation is a critical skill on which all science depends on. In light of the deception that we experience due to our limitations as humans, she suggested that the answer is to help ourselves achieve two things. First, we need to have an understanding that there are various frames of reference which are relative. Second, we need to develop a critical perspective

on the things we observe. In other words, we need to be able to value the different points of view based on certain criteria. In this situation, Marcy managed to create a form of cohesion between her philosophy about the nature of observations and their importance as a skill in science. She identified the need for overcoming the limitations in observations by responding in a critical way.

Here was Marcy, then, struggling to build and conserve a balance between her philosophical ideas about science and her practices as a teacher. What I realized was that finding a working "equilibrium" underlying this struggle was not an easy thing to do. It may be a truism to restate that her struggle was full of complexities; however, it is worth pointing out that "chaos" and "crises" are part of bringing order. More than once I identified with this passionate journey--one of struggling to establish connections among things that at first glance seem contradictory.

For most children school science may seems mysterious and irrelevant to their life. Until a teacher perceives science as a way of connecting things in the world, those children will be unable to benefit from science being taught as another school subject. Marcy places science in the context of life, she sees herself and her students as scientists, she associates the wonder of the world with the excitement that can come out of teaching science. She herself brings questions and wonders about things, without simply deferring to authority figures all the time. It is not then surprising to see her students begin to think of science as being science everywhere in their lives just like what Jacob (six years old) said in October 1997: "Everything is a little bit of science!" When teachers such as Marcy act on their ideas in ways that indicate that science is everywhere, at the same time they expand their students' world. Marcy states:

> What are we constantly doing? We constantly construct an understanding. So, think about when we tell children 'Oh, that is an interesting idea, but no that is not right. Here is what really is right.' Do we really change what they believe anyway? By telling them, or having them fill test questions, it doesn't mean that they gained any knowledge at all.

Strongly embedded in her pedagogy is the notion of constructed understandings.

Marcy was very assertive about that. Several times she emphasized that the way we learn is by constructing knowledge. As a learner, Marcy believes that it is very important to find connections with things through making discoveries about them. She pointed out to me that what is powerful in the idea of constructing knowledge is the fact that she feels a sense of ownership for what she learns. Growing up, she found out that being skilled with science "meant that you knew a batch of facts," because everyone used to "tell" her about facts and pieces of scientific knowledge. Her understanding about what it meant for her to learn science seemed to have changed as a combination of at least two factors--first, her teaching style, and second, her personal "ways of knowing."

Intuition was a significant part of Marcy's teaching style. "I don't have a plan where I am going next with something," she said, and added "it is very on the spot, on the moment kind of judgment depending on how children respond." However, she felt that intuition was not

frequently recognized as a useful kind of knowledge. "I don't see the 'on the spot teacher' who is in the process of being actively engaged in working with children as being seen even as a way of knowing, as being seen as researcher, but this is what holds everything connected together," as Marcy pointed out in one of the meetings we had. Gallas (1994) points out something similar, in other words that teacher's intuition cannot be measured, it is hard to describe systematically and therefore hard to document; however, it is the foundation on which critical and creative thinking in teaching is built. Marcy's intuition was a strategy thoroughly intermingled with her ways of knowing. What she recognized was that intuition is not valued as much as other ways of knowing, perhaps because it is such a different way of knowing. Even in her own classroom, she mentioned an example in which one student's ways of knowing were considered more valuable than others. "I think that many students see Matt as one authority because he frequently explains what he thinks, why he thinks that, where he is going next. He is logical in his reasoning," as she pointed out. For Marcy, her strategies of learning seemed to be unified with her teaching practice. This was not unusual because in her mind teaching was a way of knowing. Through her teaching, Marcy acquired a meaningful way of knowing. For example, challenging students' ideas, encouraging them to explore their interests, and actively working with them as co-learners to discover new things were valuable ways of knowing for Marcy. The notion of teaching as learning--i.e., as a way of knowing--is described in Osborne's (1998) argument that through teaching, the teacher becomes a learner. An important feature of both her teaching and her learning was their flexibility. For her teaching, she did not have a systematic lesson plan which she followed every time she taught; for her learning she believed in discovering and constructing new ideas. Neither her teaching nor her ways of knowing could be bound in a well-defined container. Once more, there was evidence of her imagination and her ideas being freed.

A more articulated notion of her beliefs about the characteristics of learners in science could be seen in her analogy of children as scientists. The main similarity between children and scientists, as Marcy pointed out, is that both have as their goal to "discover new connections," and they constantly refine their understanding as a result of discovering new connections. Their main differences are that scientists take more rigorous measurements, have more experiences, and have more knowledge. However, she emphasized that the similarities were more important than the differences. This belief illustrated her assertion of the importance of discovering the connectedness in the world. This idea seemed to be a recurrent theme in her philosophy and her teaching practice; its worth was firmly established within every aspect of Marcy's life. Both her past experiences with science learning and her teaching experiences were a constructed framework within which she could explore her beliefs in the power of discovery. These experiences provided a stage in which Marcy came into full being, enacting her beliefs. Her ideas about learning science and her practices

provided a reliable, satisfying, and reflective arena to know herself and her students in exciting and imaginative ways.

One of the topics I talked to Marcy about was the issue of how she legitimates students' knowledge. For it appears that the process of legitimation becomes a major issue in the discussions about knowledge and power in the classroom: who decides what knowledge is, and how is this process enacted? In the classroom, the question of knowledge is now more than ever a question of who has the power to define knowledge.

Marcy provides her students with a variety of experiences in which they "legitimate their own knowledge," as she says. In other words, she wants them to recognize themselves as in power to validate their ideas and not to be dependent on others to confirm them. This legitimation process, she argues, is contextual. For example, when children express creative and imaginative ideas--such as "when you put a sea shell next to your ear, you'll hear the sea because a little bit of sea is stuck there" (Ali, October, 1997)--they validate knowledge for themselves. Other ways of this process of legitimation are giving children time to explore, observing specimens, looking at books to find out what other people have found out, encouraging multiple uses of terms, showing children's journals as sources of knowledge, encouraging them to share stories about how they learn things, discussing about some of the things that scientists have found, questioning knowledge claims, and letting them experiment to start to own some of that by constructing their own knowledge. She doesn't think that her ways of knowing are more "right" than others, thus she doesn't want to impose them to her students. Rather, she wants them to find themselves the best ways they can learn. She acknowledges that a lot of her thought processes and her reflections on this issue have to do with her father's model which she summarizes in one sentence as: "Here is how I have come to understand this." Namely, that knowledge construction and legitimation is a very personal process; by rejecting students as a part of this process is like excluding them from feeling personal ownership about the things they learn.

On the other hand, she also wants to make sure that children get the message that "it is all right for all of us to not be able to make total sense of everything at times." She once said that it took her personally a long time to be able to say, "I don't quite know how to describe that, but I think that's an important part of living and learning, how to accept that at some times at this moment and time, I can't tell you why this happens." I think this is a key problem in the process of knowledge legitimation, namely to acknowledge that as limited knowers we need to accept our limits and still pursue knowledge. Central to this is the need to search for evidence, as Marcy argues, namely, for finding something "to support or reject a certain thought that you have in mind."

Another issue that came up in discussions with Marcy was students' conceptual change; namely, how could she tell if the students changed their understanding towards one that is richer

and more "accurate." "Many students change their understanding throughout time," as Marcy observed "as a result of their investigation." For example, she gave a description from fourth grade in which most students started with "anything that lives in the sea is a fish." As the students were given opportunities for investigation such as reading books and folders, looking at pictures, discussing their questions in groups, hearing other people talking about it and so forth, "they came to a deeper understanding." Therefore, Marcy identified that it was possible that students had misconceptions which represented "an earlier stage of understanding."

Consequently, then, I asked her how could she reconcile the notion of misconceptions and her belief in the tentativeness of scientific knowledge. Immediately, she acknowledged that indeed there was a contradiction in supporting both ideas. She pointed out to me that misconceptions were "less accurate conceptions," a "there are always more accurate understandings or conceptions than we currently have." Her idea that "children form their own theories and understandings" was an effective device to accommodate the paradox of the ambivalent notions associated with her underlying beliefs about misconceptions. During my observations, Marcy was constantly challenging her students to articulate their thinking about how they could explain what they observed or read. Her students' efforts to articulate their thinking was part of the process to refine their understanding. In fact, she believed that historically the development of ideas in science was similar to the development of children's ideas. Once more, the underlying notion of constant refining of understanding was strongly embedded in her beliefs and her practices. The word "misconceptions" for her seemed to be a linguistic term that expressed the level of temporality in scientific conceptions; in other words, some ideas might be more temporal and less accurate than others. The following excerpt was taken from the tape recording made during one of our early meetings.

> Conceptual change happens when there is a change in thinking or simply a change in the connections you make. And there is a sense of when you completely change a theory, whether it's throwing out one theory or saving pieces of it. I would imagine, though, that we seldom throw theories completely. My guess is that frequently we still hold pieces of old theories. If you throw a theory completely away you no longer have anything to connect it with. I think children are refining the process they are coming up with a clear or a more elaborate understanding based on their current theories.

Marcy explained that conceptual change was the result of the "cognitive dissonance" she intended to create in children. What did she really meant by that? How could she know whether such a conceptual change occurred? These were questions that puzzled me when I first heard her talking about these ideas. "Cognitive dissonance comes down to this," she said and added "I have known *this* to be true, and I also know *this* to be true. They don't match. Wait a minute. Do I have to throw out each piece, or do I have to restructure what I currently believe, or was it all wrong? This is about how do I restructure what I thought I knew before with this new piece of information." For example, she mentioned that some of her students started with the concept that

"turtles are not reptiles." After they investigated several characteristics of turtles, the students restructured their understanding what they thought they knew before with the new pieces of information they learned. Consequently, they changed their understanding to the concept that "turtles are reptiles." It was clear in her mind that creating cognitive dissonance was both a significant role of the teacher and a necessary condition for children's conceptual change. Again her teaching practice was unified with her beliefs about how children changed their conceptions. Her experiences informed her beliefs; both constructed a model which served as referent agent to any new experiences or ideas.

Marcy provided at least four indications of "some sort of shift in children's thinking." First, she referred to the "confused look." "You ask a question," she remarked "and one starts to answer it and then stops with the recognition, 'Oh, I don't get it.'" Second, she mentioned that realizing they are confused, some children "who want to find an answer, who feel uncomfortable living in this dissonance, will say 'Oh!' and go back to something earlier and throw out a lot of pieces. Often times we don't always get it but there is still some conceptual change." The third indication that she pointed out was when children "hit an 'Aha!'" They want then to explain their new theories and their new understandings. "It may be seen or shown in their discussions, how they argue their point, how they draw their picture differently." She acknowledged, though, that some children might not want to discuss their new understandings because they might not feel certain about them. Finally, she indicated that "even in that look of 'Aha!' there is light, there is a different understanding", however, she realized that she might not be able to always get to see this "look of 'Aha!'" and she did not think that all the children could either reach this understanding.

The above indications contributed to Marcy's framework of interpretation about the meaning of conceptual change. This set of indications were representations of the realism that was woven into her philosophy of science about the constant refining of our understanding. One could see her crossing a delicate threshold between the provisional status of knowledge and its manifestations in practice. This threshold was crucial for Marcy. This was precisely her own reflective way of knowing. The realistic indications of conceptual change defined Marcy through the indications she described. Her students were the audience or the witnesses of her self-awareness that change was indeed a necessary part of her own growth. Her students were her own mirror of the meaningfulness of change.

"Emotions are constantly part of this process of change," Marcy remarked in one of our conversations. "Because change is to some degree uncomfortable. You learn to embrace change or be frightened of it. Emotions are critical on whether you decide to throw something out because it is uncomfortable." Marcy believed very strongly that "the affective has a great deal to do with change." She acknowledged that internally there is always risk associated with change: "It is not easy to throw something that you believed in and come up with something else," she observed.

Sometimes it might be painful and create discomfort. Nevertheless, she encouraged her students "not to be afraid to try, to take risks and try something new, check it out and see how it works and not to be worried if somebody says it's 'wrong.'" Originating in her multiple layers of past experiences as a teacher and as a learner, Marcy's frame of understanding did not see people as being disassociated from their emotions; therefore, change had an affective piece to it which "might be felt or observed in different parts of one's body or behavior."

Marcy does not approach emotion as separate from reason and sense perception. On the other hand she does not reject spontaneous emotions such as the reaction to intensive situations in which "you must use your intuition," as she argues. For example, there was one occasion in late October 1997 whereas she acknowledged that she felt a great deal of emotional frustration and nervousness because the adults helping her in class were in fact making things more difficult for her and the children. Her emotional reaction was not passive or involuntary, rather it was a way in which she engaged in the ongoing activities of making sense out of her classroom and to understand why things happened the way they did. In other words, her emotions can be seen as a response to construct knowledge about the world around her. They are the point of departure from which she can launch a critique of her own practices and decisions. Her emotions were not disruptions to her teaching, they were *about* her teaching, a necessary part of who she was. Emotions made a valuable contribution to her observations, thoughts and actions in the context of her classroom. As she explained, she used her nervousness and frustration to made adjustments to her teaching by asking herself "Is something valuable happening here for the children?" This may indicate also that her emotions were very closely related to her values about good science teaching and learning. It seems that emotions presupposed values, otherwise she would not show any emotional reaction that "something was going wrong" in her classroom. In a sense, though, her observation of what was happening directed and shaped, at least partially, her emotional reaction. The opposite seemed to be true also, because her emotions shaped her further observations about what was happening and focused her attention selectively on what caused her nervousness and frustration. Her emotions were constructed in the particular context she was part of and motivated her to alter her teaching plans. It seemed to me that her emotions in this case contributed to the development of knowledge about the situation in her classroom. They were vital parts of the construction of her knowledge and herself.

The cognitive and affective duality of conceptual change led Marcy and me to a discussion about the role of values in the process of learning and change. She pointed out to me very clearly that the interactions among ourselves, our experiences, and our readings "have a tremendous impact on how you value yourself, how you value what you know and who you are." "What are you supposed to know? What messages have you gotten about what kind of knowledge is important? How is it going to help you?" were puzzling questions that concerned Marcy when she

was thinking about the interplay between personal values and values implied or imposed by our learning or societal environment.

Marcy's ideas about learning and change were grounded so strongly in practice that they empowered the context within which they were constructed, thus preserving that context. Her beliefs about how children learned best and the manifestations of these beliefs through her teaching practices affected her and stayed with her in the context of her past teaching and learning experiences where she had acquired them. She employed both her beliefs and her practices in a single experiential reality because they became the embodiment of her personal growth. For example, her belief that children need to construct their understanding was rooted in the deepest layers of not only her mind but also her heart because this was how she experienced understanding herself.

> Once we would pretend to live in Hawaii and children started with a variety of pictures to explore life in the ocean. Each group had a packet of photographs and they were to classify them based on what they knew at the beginning. And then through a series of lab projects such as observing some dry specimens, reading and so on, we began looking at 'what do you think this is?' and then having kids defend their position to other people. They described and explained things, and it went on for a series of five months investigating this. We tried to simulate things, we tried to move like sea animals, we did a lot of other sorts of hands-on things. Many people changed their understanding throughout that time.

Marcy's rationale for teaching science was very dynamic. She knew how to deepen children's experiences, by bringing together a variety of opportunities for them. She knew that she wanted to teach science as investigation and as process, because she believed this was the most beneficial way for her students. On the other hand, she admitted that "because we are in a society that values information," she did work towards talking about some of the general concepts that were aligned with views expressed by the National Standards and by the district. However, she made it clear to me that these views by the Standards and by the district were at a different level in terms of what quality Marcy worked toward in her classroom. "Those [the standards and/or the district's views] are not really the things that I look for when I'm looking at what makes the quality of what we are doing in the classroom." All these views were tempered by the realism in her classroom. The following example she mentioned illustrated the ultimate question, "Does it make sense at all to teach science to fulfill some standards?" The answer might be surprising for some people.

> We went to a science museum. After the children explored for a little while, they took a piece of paper and drew a picture of something that was important to them and then wrote about it. And we've been studying that in our class and we observe real reptiles, we have our rubber reptiles, and we are reading about them. One of my students wrote, 'a snake is not a reptile. It not cold-blooded. So, I went and get to spend time asking questions. That was a reminder once again of such terms such as cold-blooded, that the term is very confusing, and very difficult. It reminded me also that lots of times if you ask adults you'll find a lot of them can't answer the difference between cold-blooded and warm-blooded. And this particular child's response, she was looking at the snake in this warm cage with extra light in it to help keep it warm, so how could it be a cold-blooded animal! She certainly heard warm-

> blooded, read warm-blooded, and we certainly talked about reptiles being cold-blooded. She's seen them in different places, she's written about them, we've talked about them, but that didn't change her concept of it. It seems that those words [cold-blooded] didn't make sense to her. No matter what I do or what she does at this point the concept may not completely change. Well, I don't find myself up in arms about that. Or it doesn't mean that 'Oh, my gosh, I'm not a good teacher, or she is not a good student.'

A traditional response to this situation would be perhaps that the student failed because she did not learn how to use the correct scientific terminology. Therefore, when this particular student is asked a multiple choice question on a state or national standardized test, she will fail to provide the correct answer. Marcy's last sentence in her above statement expressed the underlying or overt expectations found in a framework of thinking that is bounded by standards and information that is "testable." What most of us seem to forget, though, is that this child has had so many exciting opportunities to explore things about reptiles that the rest of us will probably never have. For Marcy, respecting students' thinking, challenging them with new ideas, and promoting process skills were the most significant features in her philosophy of teaching science. Marcy was excited when either her or her students were frustrated by the difficulty of understanding something. Many times she would share her uncertainty, reflecting on what she used to think and how she had changed her understanding. She wanted to show her students that it was all right to be confused and still struggle for understanding. She wanted them to see that "not everything is great," but they had to enjoy the process and take risks to try new ideas.

Her personal struggles to learn how to value her ways of knowing found a meaningful place in helping children "to come to an understanding that they are the authority about themselves." "I think it's very important," she said, "as you want children to become independent, for them to have a sense that they are the ones who know what they need next. 'Can you help describe what would be useful for you to know? You know what you are interested in. You know how to help me connect this with something else.'" Her experiences and her emotions in dealing with herself as a knower provided her with the rationale to empower children to pursue their interests and their passion for what they wanted to learn. Through a lot of self-reflection on her feelings, emotions, and ideas she would direct her decision-making and her planning toward what her students needed and how she could encourage them to pursue their interests. Here is an episode from the process of interviewing one student. Her rationale for interviewing each student in the class several times throughout the year was "to find out their learning strategies and their ways of thinking, since every student was doing something different."

> The student jumped off his seat and went to find the book in which he found the information he had talked about earlier. Marcy was waiting patiently, looking at her student's notebook which was wide open in front of them throughout the interview. After a few seconds, the student came back running with a book in his hands. He was smiling. He opened the book to a page and showed her a huge boas. "Look!" he said, "Isn't that the biggest snake you've ever seen?" Marcy smiled warmly and replied "Wow! This is a huge snake!" The student looked at her--it was one of the few times during the whole interview

> that he looked her in the eyes--and smiled too. It filled my heart with joy to see the student's sharing of excitement about something he obviously was thrilled about.

The social context in Marcy's classroom was such that students in no way felt threatened about sharing their ideas or their excitement. They knew that Marcy cared about them and respected their own ways of learning things. She would look deeply into the creativity underlying the teaching of science. For her, learning and teaching were a creative process, an expression of who she was as an individual. She continued through her teaching to be engaged in an imaginative process of creating new opportunities for learning, both for her students and herself.

Discussion: Some Epistemological and Affective Dimensions of Marcy's and Barbara's Work

The teachers' views discussed here provide evidence of several elements that seem to interact in the dynamics of the relationship among philosophy of science, emotions and teaching practice. These elements are teachers' ways of knowing and their images of themselves as knowers, their beliefs about the nature of science, and the emotions that are explicitly or implicitly part of teachers' personal and professional life.

Both Barbara and Marcy at various times identified their earlier experiences, positive or negative, as very important parts of their lives, and large determinants of both their philosophy of science and their teaching practices. My recognition of this occurred after I had talked to them several times, and I realized how essential it was for me to reflect on my own past experiences. I had had experiences similar to Marcy's in the ways I was taught science in grade school. Coming from a different culture and being educated in a different school system did not seem to make a difference in this case. Despite the many years of teaching experience that set us apart, we were concerned by some similar issues. How can we improve our own science teaching and our understanding about science? How can we better understand the interactions between our philosophies or ideas, our emotions and our teaching practices?

It is useful to think about the framework of ideas about the nature of science and the framework of enacted beliefs in teaching practices as transformative agents of each other. Their connection is a dynamic relationship full of complexities. Sometimes it is hard to identify the underlying relationships that transform a belief into a practice and the opposite. Other times it is valuable to try and identify which agent is more likely to be the stronger and under what conditions. In Marcy's case it seemed that her philosophy about science played a significant role, perhaps sometimes more significant than her practice. This may explain the occasional existence of "crises" between her beliefs and her practices. She allowed her emotions and her thoughts freedom to explore ideas that initially would only create conflict with her practice. On the other hand, Barbara seemed to prefer a safer ground. Her practice was the primary transformative agent. One had to look more deeply to explore potential inconsistencies. Their struggles, although of a

different kind, were meaningful and necessary parts of their lives. These struggles were meaningful because they provided significance to Marcy's and Barbara's beliefs and actions.

Looking now at both Marcy's and Barbara's beliefs and practices about learning to identify some of the specific features that account for their philosophies, it is clear that their own ways of knowing contributed a significant share. Both of them were favored with excitement and love for learning new things about science. Any potential conflicts or inconsistencies were easily dismissed by their powerful certainty which they established in their practices about how science learning should occur. Any opposing beliefs were constantly renegotiated within this strong frameworks of beliefs. They were less likely to tolerate ambiguity in their beliefs about learning than in their ideas about the nature of science. The complexities, of course, were there, for they were real in everyday basis. However, due to a combination of their understanding of their own learning styles and beliefs and their past teaching experiences, they were able to integrate their successes and their concerns in a rather intuitive way. The acceptance and respect of student ideas, and the understanding of the importance of encouraging students to discover or construct knowledge were in a dialectical relationship. Marcy would perhaps tolerate more relativistic perspectives than Barbara did; however, when it came down to the approach with which students learned, they both gave meaning to a creative process of intuition. But this intuition did require a dynamic balance of their beliefs and their practices about learning which led to their integration in pedagogical practices.

Marcy's theoretical interpretations of her actions in her classroom are contextualized by the particularities of her emotions--such as caring for her students, and her personal sense of what constitutes good teaching. Such experiences and their interpretations create what Kincheloe and McLaren (1994) call "synergistic interaction" between theoretical understanding and the intimacy of one's own autobiography. Marcy is very *eclectic* in the sense that the context is more important than a general structure that needs to be followed in her (science) teaching. She acts on her insights and intuition and places herself theoretically within a complex web of interactions with her students in which she does not loose touch with her emotions in her everyday life. For example, she has often talked about how she has felt as a learner both in her childhood and now. She brings particular experiences into focus, such as her immense value of discovering connections in the world, in a way that she grounds them through a consideration of the emotions she experiences. Her understanding and her specific interpretations of what happens in her classroom are derived from and interact with her autobiography. As she connects her individual stories with the classroom stories her emotions play a major part.

Marcy's empathy for her students (she was marginalized in science as a student) is central to the process of validating her students' knowledge and their ways of knowing. As Collins (1990) writes "personal expressiveness, emotions, and empathy are central to the knowledge

validation process" (p. 190). Marcy's major ways of responding to her students are caring and compassion for them as individuals. For example, Marcy explained that she is very sensitive to children's reactions and emotions about how they know things because she doesn't want to discourage them by communicating that only "right" answers are acceptable. She often argued that children are very sensitive and if the teacher creates negative emotions by rejecting their ways of knowing then children will be discouraged from thinking for themselves. She also pointed out that she wants to help children understand that "it's OK not to know," and that they should not feel guilty or scared because of that. Marcy's thoughts and experiences explain how emotions, values, and ways of knowing may be inseparable from teachers' work and from the construction of one's self as a teacher.

There are various epistemological and affective issues that enter teacher's work such as issues of knowledge, nature of science, values, and teachers' image of themselves as knowers. These issues reveal aspects of the complexities of teachers' work. It is, therefore, useful to consider these issues and their accompanying complexities in any effort to interpret teachers' classroom practices. Marcy and Barbara have shown that there are many issues embedded in teachers' practices of science and their personal development. For example, views of the nature of science can shape the context of teaching and learning, the perceptions about how students learn science, the teachers' own sense of themselves as teachers and knowers, and the teachers' own conceptions of what constitutes knowledge and valuable ways of knowing. On the other hand, what both Marcy and Barbara have revealed is that the particularities of the classroom context--social and organizational context, students' needs and so forth-- shape the nature of their beliefs and their ideas.

Teachers may hold some views and be unaware of them--such as in Barbara's case of using interchangeably the meanings of "discovery" and "construction" of knowledge--or be aware of internal inconsistencies among their beliefs--such as in Marcy's case of not believing in "right" and "wrong" scientific conceptions but still using the term "misconceptions" to characterize some students' conceptions. Nevertheless, whether aware or unaware of these views, teachers interpret their practices, make decisions, and act in the classroom on a long-term as well as on a day-to-day basis. Both their beliefs and their practices are informed by their understanding of themselves as knowers (and the limitations and inadequacies of their knowing), by their past teaching or learning experiences--positive or negative according to their assessment--and by their knowledge of what science is. Teachers' beliefs and practices are in a constant and dynamic interaction; this interaction changes over time and over different contexts. For example, Marcy indicated that she went through significant changes in her views and her practices of science during the last ten years: changes in her assumptions about knowing, and in her ways of teaching science. Also, although within the context of views on the nature of science she experienced moments of "crises" or

contradictory understandings, within the context of learning and teaching science her practices were the primary transformative agents through which she examined her philosophical ideas.

Both Marcy and Barbara have shown that the affective domain--emotions and feelings--and teachers' and students' values are important dimensions of teaching science and they explicitly or implicitly influence teachers' personal and professional development. I share Jaggar's (1989) account of emotions as intentional, as social constructs, as ways in which we engage actively and construct the world, and as closely related to values. For example, Marcy, reflecting on her views about the nature of science, indicated the complex ways her emotions entered her teaching and her ideas created a contradiction in her for which she sought resolution. Barbara, spoke repeatedly about how excitement and wonderment became necessary parts of success in her teaching of science.

Many studies have been carried out in science education to evaluate the student affective outcomes (see Laforgia, 1988). Interestingly enough, educational researchers have largely ignored affective dimensions in teachers' work. "The notion that teaching is not just a technical enterprise," argues Huberman (1996), "but is also inextricably linked to personal experience; emotional life; interpersonal dynamics; and, in its rendering, to self disclosure is a relatively new one in educational research" (p. 130). Further, Huberman acknowledges that "we have thoroughly studied variables like personal experience and emotional life in children but not, I would claim, in their teachers" (p. 130). Even the few studies that have been reported about teachers have been conducted to investigate teacher "attitudes" towards the importance attributed to student affective outcomes or the priority teachers place on affective concerns (see for example Prawat, 1985). Indeed, many researchers (and theorists) have attempted to separate thoughts from emotions and remove emotions or at least diminish their importance (Thayer-Bacon, 1993). Especially the relationship of affective dimensions and epistemological dimensions in teachers' work has yet to be studied. There might be several reasons for this; I want to share a few.

First, the long term emphasis on students' and teachers' behavior (process-product research) as the only valid and scientific ways to study educational matters has led to a lack of concern for issues of affect. Also, the inability to measure, describe or "fix" emotions has made their study more difficult. The assumption that affect and emotion are irrational since the time of Socrates (Bills, 1976) and cannot be studied scientifically, as all sciences should be, has resulted in the role of emotions in teachers' practices being ignored. Third, the Cartesian dualism of mind and body, reason and emotion contributed to a false polarization (Fricker, 1991) that has been perpetuated in schools privileging the research of teachers' cognitive thinking. It has been usually assumed that by *only* studying teachers' thinking--since emotions have been judged to be *misleading*--then we can understand their practices. Fourth, research on affect has always been considered more complex and difficult than research on cognition (Simon, 1982, as cited in

McLeod, 1988). Finally, issues of affect and emotions have been usually associated with women and feminist philosophies and therefore they have been excluded from the dominant patriarchical structures as worthwhile and valid researchable issues.

When teachers are engaged in their teaching practices they often express many emotions such as frustration, joy, surprise, or anger. These emotions can be positive or negative and manifest themselves in different ways fulfilling a variety of functions, sometimes perhaps through action or (and) speech. For example, there was an occasion in which Marcy became frustrated because her aid "gave too many directions to the children to a point that she [the aid] inhibited their imagination." Marcy felt that the work in small groups became "dry" and "unimaginative," and the children seemed "bored" or "unhappy," because they were told by the aid what *exactly* they needed to do. Then Marcy decided to bring the whole class together and discuss their work, so that they can re-focus on things that children *wanted* to do. The significance of emotions in teachers' work may be realized further in this event in that emotions reveal a "truth" about a situation which rational thought processes may ignore or hide. Both Marcy and her students *felt* or *seemed* to be unhappy with what they were doing, therefore they realized that they needed to do something. Research on these emotional reactions of teachers to their work should be helpful in planning, social relations, sharing, the pursuit of their personal growth and development and the growth of their students. By seeking ways to establish contexts that promote constructive positive emotions and caring, students, teachers and researchers can facilitate constructive action, stimulate skills and habits of self-control (van Dam & Steutel, 1996) and bring changes to all aspects of education. I claim that *transforming* these emotions (for both teachers and students) through careful exploration and refinement is both an educational and an aesthetic process. Marcy transformed her emotions of frustration into constructive positive emotions when she shared them with her students in the whole class meeting. After she and her students shared how they felt, they re-interpreted what they were doing, and they re-directed their focus.

It is therefore of primary importance that educational researchers reassess the role of emotions in relation with epistemology and what there is to be gained from privileging a *holistic* attention to teachers' work, one that does not ignore affectivity any more. Jaggar (1989) adequately describes this holistic picture when she argues that "rather than repressing emotion in epistemology it is necessary to rethink the relation between knowledge and emotion and construct a conceptual model that demonstrates the mutually constitutive rather than oppositional relation between reason and emotion" (p. 141). Emotion and reason are interdependent because reason presupposes emotion--what is rational depends on emotional preferences--and emotion presupposes reason--our emotions require rational interpretation if they are to come above ground (Fricker, 1991).

What I want to argue, then, is that we need a new frame of reference for understanding teachers' work, one that views teachers from this holistic point of view. How can we construct this holistic picture? Affect is a result of interactions among teachers and their students, it cannot be apart from any cognitive dimensions of personality (David, 1976) thus it is not a thing that can be ignored. If we pay attention to teachers' emotions we may be able to interpret them sensitively and accurately, and to effect changes in what is accepted as rationality (see Fricker, 1991). Fricker (1991), in particular argues that: "Given this possibility for the nurturance of new emotions which are not yet sanctioned and codified by accepted rationality, and given that the status quo relies on our emotional as well as rational acquiescence, then emotions can emerge as a potentially subversive force" (p. 18). If we cease to think emotions as irrational then we can view them as "instruments of freedom rather than tools of self-oppression" (De Sousa, 1990, p. 446) and *invalid* ways of knowing. On the contrary, as Sartre says: "Emotion is a certain way of apprehending the world" (cited in Bantock, 1967, p. 70). Emotions are defined by Sartre as ways of being in the world, in other words, as ways of knowing the world. I believe that emotions may be helpful and even necessary to the construction of knowledge (see Jaggar, 1989).

Teachers' emotional experiences constitute *stories* because they are commonly said to involve desires as components (see De Sousa, 1990)--such as Marcy's desire, expressed as a question, whether there was something valuable happening for the children. Emotions are socially constructed (Jaggar, 1989) and so are teachers' stories. This suggests that exploring the story-like structure of teachers' emotions can lead to recognizing that these stories "are not all of a piece... they have parts that might be recombined in different ways" (De Sousa, 1990, p. 445) and be reinterpreted. The advantage of this process for both teachers and students is the establishment of a rich emotional flexibility that allows them to look one story in the light of another. For example, reinterpreting how Marcy and her students felt in various occasions allowed them to identify when they felt joy for what they were doing. That, surely, is what education is all about: to be able to become part of many people's stories by nurturing caring, respect and joy. Only then may emotions become a true *political force* (Fricker, 1991) for changing the ways we interpret educational matters.

Embedded in both Marcy's and Barbara's pedagogy was significant reflection on both their practices and their philosophical views about teaching science. Their struggles to find a relationship between their philosophies and their practices of science revealed the ways their rationale was related to their relationships with their students. Both Marcy and Barbara saw their students as mirror images of their own personal struggles for understanding and for establishing a pragmatic relationship between their beliefs about science and their teaching of science. Marcy's beliefs about the existence of multiple ways of knowing and her emphasis on respecting that students have different ways they learn science affirmed her own personal idea about emancipatory

learning. In other words, she found a link between her personal ways of knowing, her ideas about herself, and her belief about how students should learn science. Her unifying idea was the search for "connectedness" in the world. This idea sought to connect past or present events, intentions, ways of knowing, approaches to teaching, emotions and values. The realization of the complexities embedded in teachers' work was a necessary part of her struggle and a result of her reflection.

Webb's and Blond's (1995) argument for a recognition of an epistemological role for caring in teaching is also an important element revealed in this study. For example, Marcy's and Barbara's caring revealed aspects of their knowledge *about* themselves and their students, and *with* their students through a sense of care for self and the other (Hollingsworth et al., 1993). Caring (Noddings, 1984, 1988, 1992), as well as emotions as I have described them earlier, are central to teachers' work and constitute legitimate ways of knowing. Knowledge, in my view, is not limited to what we know, but to how we feel in relationship with others. Knowing is *relational* (see Noddings, 1984, 1988; Hollingsworth et al., 1993, 1994) just as affect is relational too, because they both develop as consequences of the interactions among people, situations and objects. Marcy's and Barbara's knowledge from caring and interacting with their students involves a "feeling with" (Thayer-Bacon, 1993) their students, and it stresses engrossment (Noddings, 1988; Thayer-Bacon, 1993)--respecting, valuing the other and giving nonselective attention to him or her. In particular, Webb and Blond (1995) argue that caring is part of knowing in a teacher's knowledge: "the knowing is in the relation" (p. 614). "In a paradigm of relational epistemology," writes Thayer-Bacon (1993) "relational beings pursue trustworthy knowledge by way of conversation with others in the market of ideas" (p. 337). These claims indicate how complex the nature of teacher knowledge is and in talking about knowing, caring, and affect we need to acknowledge the interaction of multiple ways of knowing.

There is a final comment to be made concerning the relationship between teachers' philosophies of science and their teaching practices of science. Both the philosophies and the practices have interconnected and interacting perspectives, what Lyons (1990) calls "nested," meaning that each influences the other in the particular context where the interaction takes place. The idea of a "nested" relationship is powerful in terms of acknowledging the complexities involved in exploring the role of teachers' philosophies in classroom practices. Any efforts to reduce this relationship to a number of conditions apart from its context of development fail to acknowledge these complexities.

Implications for Further Explorations

Several implications follow from recognizing the epistemological and affective dimensions in science teachers' work:

1. Besides the subject matter and pedagogical knowledge in science, there are several epistemological and affective issues that come together in teachers' work. Understanding teachers' emotions may contribute to the understanding of how they construct knowledge; more research is needed towards this direction. The opposite is also true; the growth of knowledge about teachers' epistemologies in science may contribute to the development of appropriate emotions in particular contexts and with specific students. Jaggar (1989) argues that there is a continuous interaction between how we understand the world and who we are as people.
2. Teachers may hold some views and be unaware of them. Nevertheless, whether aware or unaware of these views, teachers interpret their practices, make decisions, and act in the classroom on a long-term as well as on a day-to-day basis within a context that they are epistemologically interconnected with themselves and their students as knowers.
3. Emotions play a vital role in teachers' work and the development of their knowledge about teaching science. Certain emotions may be *epistemologically advantageous* (Jaggar, 1989) in approaching the world of science as a relation of affection, empathy and love (see Keller's account on Barbara McClintock; Keller, 1984).
4. This work contributes and extends the existing research that explores the epistemological and affective issues that shape elementary science teachers' work and the respective complexities of teachers' and students' lives and experiences. It also offers an alternative framework to current discussions about the relationship between teachers' beliefs and classroom practice by suggesting to move the emphasis from the "what" to the "how". By examining the epistemological and affective context of teachers' classroom experiences, researchers can describe how and why knowledge and values are related to teachers' practices and their students' learning. This study is only a preliminary sketch for a framework that considers epistemological and affective dimensions in science teachers' work. More research is needed to understand these dimensions in the complexities that characterize teachers' work and their lives.

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